DATA EVALUATION RECORD

PC Code 128931/100094 **Dicamba, DGA and BAPMA Salts**

Reference: Jones, Gordon Travis. 2018. Evaluation of Dicamba Off-Target Movement and Subsequent Effects on Soybean Offspring. University of Arkansas, Fayetteville, 197 pages

Test material: Clarity (Reg No. 524-582) and Engenia (Reg No. 7969-345)

Common name: dicamba

Study classification: Supplemental

Primary Reviewer:	Chuck Peck EPA Reviewer	2018.10.31 11:53:52 -04'00' Date
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This review summarizes the evaluation of primary (*i.e.*, spray drift) and secondary (*i.e.*, volatility) drift of dicamba products onto nontarget soybean plants.

Reviewer Conclusions:

This study evaluated the impact on non-dicamba resistant soybean from nearby dicamba applications, such as those made to nearby dicamba tolerant soybean and cotton in a series of separate but interrelated experiments (presented in separate chapters). The study examined the distance dicamba moves during an application using commercial application equipment (primary and secondary drift, Chapter 1), as well as the effects of drift events upon soybean offspring (seedling emergence and vigor, Chapter 2). Additional experiments were designed to investigate the effect that adding glyphosate to dicamba has upon soybean growth and yield as well as possible effects on offspring (Chapter 3). Lastly, an experiment was conducted to determine the extent of secondary (volatile) drift of two formulations of dicamba under mid-summer conditions by controlling for primary (spray) drift (Chapter 4).

Primary and secondary drift of dicamba exceeded 150 m in 26 trials (corresponding to 5% soybean injury, *i.e.,* visual signs of damage). Instances of height reduction (5%) differed among growth stages. The greatest distance for height reduction occurred when applications were made at the start of flowering (R1 growth stage, 83.4 m). Impacts on yield (harvested seed weight) were greatest nearer the application plots with a steep reduction in response pattern moving away from the treated plots. Soybean yield reduction was generally non-uniform and non-dose responsive for several trials, with the greatest distance to 5% loss in yield occurring at 90.4 m after a drift event following application during full bloom (R2 growth stage). It should be noted that the study used nozzles producing a very-coarse droplet spectrum, which is not permitted for formulations of dicamba employing over-the-top applications (labels require the use of ultra-coarse nozzles).

Drift trials established at early reproductive stages were more damaging to parent soybean; however, applications to late reproductive soybean were more detrimental to the soybean offspring. A correlation analysis was conducted to evaluate the pairwise associations among parent plants exposed to dicamba drift and offspring observations. Results indicate that the percent of parent pods malformed resulting from dicamba drift events at the beginning of seed development (R5 growth stage) displayed the highest correlation coefficients with offspring emergence ($r = -0.37$, $p = 0.0082$), offspring vigor ($r = -0.57$, $p = < 0.0001$), offspring injury ($r = 0.93$, $p = < 0.0001$), and amount of offspring plants injured ($r = 0.92$, $p = < 0.0001$). As a result, soybean damaged from dicamba drift during stages of reproduction can negatively affect offspring. Parent pod malformation may be indicative of injury to the offspring from exposures occurring at the R1-R3 stages however increased offspring effects are observed from exposures at the R4-R6 stages.

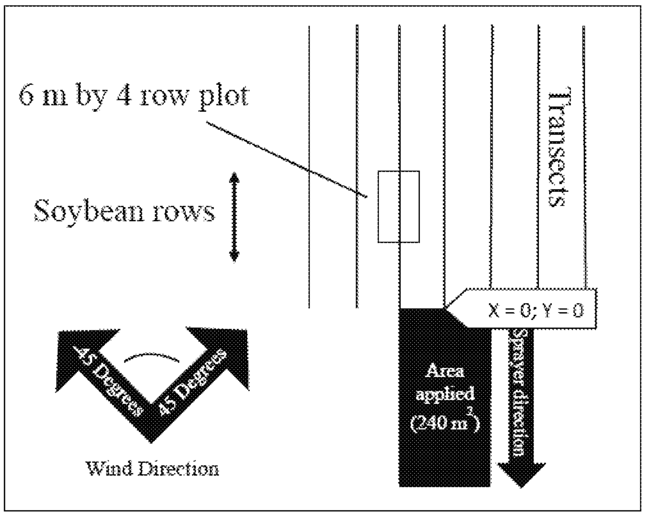
When low rates of glyphosate were added to low rates of dicamba and applied to soybean at R1 growth stage, plant injury (leaf malformation) at 28 days after application (DAA) was increased over low rates of dicamba alone. Dicamba also caused damaging effects to soybean offspring in this study; however, the addition of glyphosate did not increase further impact on soybean offspring.

Diglycolamine (DGA) and N,N-Bis-(aminopropyl) methylamine (BAPMA) forms of dicamba are suspected to be similar in terms of primary drift. However, in another study, injury caused by secondary drift from BAPMA dicamba was less than DGA dicamba at 21 days after application (DAA). The maximum distance to 5% soybean injury from primary and secondary drift was 168 m for the DGA salt and 96 m for the BAPMA salt. The maximum distance to 5% soybean injury from secondary drift of the DGA salt (120 m) was over twice as far as the BAPMA salt (54 m).

Chapter 1: Off-target Movement, Primary and Secondary Drift

Materials and Methods

To evaluate possible results of over-the-top application of dicamba in dicamba resistant (DR) crops, field trials were designed to examine off-target movement using proposed sprayer setup recommendations. Twenty-five field experiments were conducted in 2014 and 2015 at the Northeast Research and Extension Center (NEREC) in Keiser, Arkansas, with one additional experiment conducted at the Lon Mann Cotton Research Station (LMCRS) near Marianna, Arkansas in 2015. All drift experiments were conducted using the commercially available DGA formulation of dicamba branded Clarity® (BASF Corporation). Timing for dicamba applications was restricted to the reproductive stages of R1 through R6. Dicamba was applied at 560 g ae/ha (0.5 lb ae/A, maximum label rate for over-the-top applications) using a Bowman Mudmaster Sprayer traveling 16 km/h (10 mph) employing a 60-cm (23.6-in) boom height above the soybean canopy. The sprayer was equipped with TeeJet AIXR 11003 nozzles and calibrated to deliver 93.5 L/ha (10 gal/A) at 275 kPa (40 psi) to achieve a very-coarse droplet spectrum. It is acknowledged that the current nozzles recommended for the new formulations of dicamba do not include AIXR 11003 nozzles. **Reviewer's note: Over-the-top applications of dicamba products, such as Xtendimax and Engenia, require the use of ultracoarse nozzles, which are specified on the products' websites.** The application area was 8 m by 30 m in size where the wind blew parallel or less than 45 degrees to the soybean rows and 8 m by 60 m in size where the wind blew perpendicular or greater than 45 degrees to the soybean rows. At 28 DAA in experiments where the wind was greater than 45 degrees from the soybean rows, three transects were established across rows extending downwind from the area sprayed. The centers of transects were initiated at 18, 30, and 42 m into the 60-m application swath. Each plot was four rows, spaced 96 cm and 12 m in length, with only the center two being used for data collection. Plots extended along transects until no injury was observed or the end of the field was reached. In experiments where the wind was less than 45 degrees from the soybean rows, transects were laid out extending downwind from the center and to the left and right side of the downwind edge of the 8- by 30-m application area in four-row increments until no injury was observed laterally. Plots were established down rows in 6-m lengths until no injury was observed. Again, rows were spaced 96 cm, and data were collected from the center two of four rows (**Figure 1**; extracted from thesis). Grid coordinates were given to each plot with x=0 and y=0 being the center of the downwind edge of the application. Soybean injury and three canopy heights were recorded at 28 DAA for each plot. A visual scale from 0 to 100%, with 100% being plant death, was used to estimate soybean injury (no further details on the visual scale method were provided). The percent of pods malformed and the height to the terminal of three individual plants per plot were recorded at soybean maturity. Both canopy height and mature height were converted to a percent relative to uninjured plots by selecting three random plots having 0% soybean injury (outside of the drift plume) at 28 DAA. Percentage of pods malformed were recorded on a 0 to 100% scale, with 0 being no pod malformation and 100 being all pods having malformation. A small-plot combine was used to harvest plots, and grain yields (based on weight) were corrected to 13% moisture before being converted to a percentage yield relative to uninjured plots.



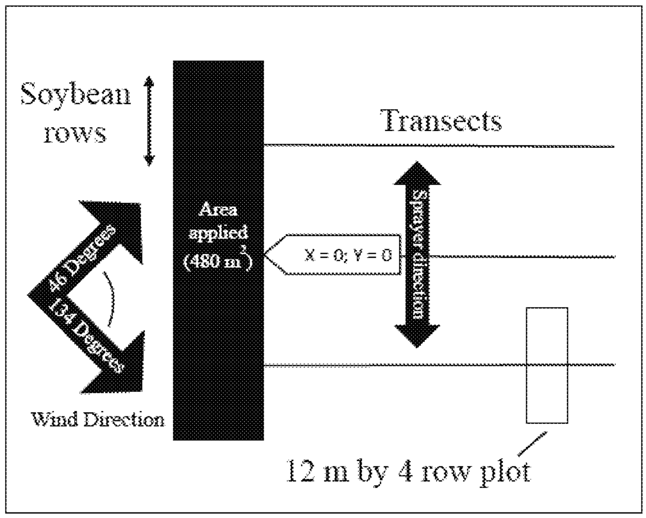


Figure 1. Design of drift trials with wind predominantly occurring (A) down rows and (B) across rows

Chapter 2: Summary of Conclusions

Association analysis and non-linear regression techniques were used to examine the effects of 26 field-scale drift trials conducted in 2014 and 2015 during soybean reproductive development (R1 through R6). **Table 1** presents the study results. The greatest predictors (injury, height reduction) of soybean yield reduction generally occurred and had steeper relationships after drift events at R1 growth stage than at later stages. Using non-DR soybean as an indicator, dicamba was documented to move and cause impacts as much as 152 m from the application area (distance to 5% injury). Instances of height reduction (5%) differed among growth stages with the greatest distance occurring at R1 (83.4 m).

Soybean yield reduction (as a measure of grain weight) was erratic with the greatest distance to 5% loss in yield occurring at 90.4 m after an R2 drift event. Overall, early and full-flowering stage soybean (R1-R2) appears to be more sensitive than later reproductive soybean (R3-R5) to mature plant injury, height reductions, and yield loss.

While meteorological data were collected, only the average and maximum wind speeds during the applications were provided in the study report. As a result, it is not clear if these trials are reflective of worst case temperature and relative humidity conditions. There did not appear to be any correlation between the wind speed and the injury documented.

Table 1. Growth stage, and maximum and average wind speeds during application and the calculated distance to 5% observed soybean injury, 5% reduction in height at 28 days after application, 5% reduction in height at harvest, 5% pod malformation, and 5% reduction in yield for drift trials[ab]

Growth Stage	Trial	Maximum Wind Speed (km/h)[c]	Average Wind Speed (km/h)[c]	Calculated Distance to Effect (m)				
				5% injury	5% reduction in height, 28 DAA	5% reduction in height, harvest	5% pod malformation, harvest	5% reduction in yield
R1	1	19	16.9	128.2	49.6	72.8	85.6	25.9
	2	19.8	15.1	94.1	42.1	79.2	54.4	14.6
	3	19.3	16.3	91.6	38.5	75.1	66.3	33.9
	4	18	15.8	120.1	83	51.5	77.6	9.7
	5	16.8	12.1	75.1	52.1	24	41.4	18.5
	6	15.3	16.3	64.4	36.8	83.4	49.6	42.8
R2	7	14.5	12.6	36.4	53.3[d]	42.4	40.6	40.9
	8	17.7	14.9	85.5	34	36.6	52.4	10.1
	9	11.9	10.2	116.7	54.3	23.4	95	0[e]
	10	15.4	11.1	152	14.5	17	139.5	3.7
	11	12.9	12.1	60.6	0[e]	15.4	60.6	90.4[d]
	12	13.7	8.5	30.3	-[f]	0e	36.2	0[e]
R3	13	10.5	9.1	39.2	8.2	6.6	25.1	5.7
	14	15.3	14	30	0[e]	0[e]	27.9	11.2
	15	21.2	16.2	61.0d	36.2	7.5	34.1	0[e]
	16	14.6	12.6	50.3	24.1	22.1	23.4	33.5
	17	14.3	11.2	16.5	0[e]	0[e]	18.1	0[e]
R4	18	15.6	13.1	17	0[e]	0[e]	22.7	10.2
	19	14.6	13.4	16.1	8.2	0[e]	2.8	0[e]
R5	20	14.6	13.4	27	0[e]	0[e]	15.7	0[e]

[a] Trials with less than 5 data points were excluded from the analysis
[b] Distances were calculated using the reverse prediction function in JMP Pro 13 (SAS Institute, Cary, NC)
[c] Wind speeds were recorded at 1 sec intervals during application.
[d] Value recorded from the equation resulted in extrapolation; therefore, the furthest recorded distance is used.
[e] Not a significant regression; therefore, a distance of 0 m was used.
[f] Data not recorded.

Chapter 2: Response of Soybean Offspring to Dicamba Primary Drift from Previous Year

Materials and Methods

Field drift experiments were conducted in 2014 and 2015 at the University of Arkansas NEREC and offspring experiments were completed at the Arkansas Agriculture Research and Extension Center (AAREC) in Fayetteville, AR, in 2015 and 2016. For more information on the 2014 and 2015 field drift experiments, please refer to the previous section.

A sample (approximately 1 kg) of seed was taken from each plot after harvest and placed in a freezer maintained at -10°C until the following spring when planting occurred. Seed collected from the 2014 and 2015 drift trials were planted at AAREC in 2015 and 2016, respectively, at 25 seed/m row in 6-m-long plots on a 91-cm spacing. The site consisted of a Captina silt loam (Fine-silty, siliceous, active, mesic Typic Fragiudults) with a pH of 6.1 and 1.18% organic matter. The field was furrow irrigated weekly, if at least a 2.5-cm rainfall did not occur. Initial planting in 2015 was April 26; however, injury in the form of stand loss was caused by preemergence (PRE)-applied flumioxazin (Valor SX), after which the test was replanted in a different field on June 25. No PRE herbicides were used thereafter to avoid herbicide injury. In 2016, initial planting occurred on May 19. Stand loss occurred due to soil crusting and pigeon (*Columba livia*) feeding in isolated areas of the field to the extent that the experiment was replanted on June 9. All varieties were glufosinate-resistant for ease of weed control. Multiple varieties were used but all were indeterminate growth habit to reduce variability in response. Experiments were kept weed free with a POST application of glufosinate (Bayer CropScience) at 595 g ai/ha (0.53 lb ai/A) and S-metolachlor (Syngenta Corporation) at 1,390 g ai/ha (1.24 lb ai/A) at 21 days after planting (DAP) followed by a second application of glufosinate two weeks later. Measurements from the offspring included emergence (% of planted seed emerged), vigor (1 to 5), injury at 21 DAP (% visible injury on a 0 to 100% scale with 100% being plant death), number of plants malformed per plot (converted to % of plants showing malformation), and grain yield adjusted to 13% moisture (kg/ha). Soybean vigor was rated on a scale of 1 to 5 for each plot using the following criteria: 1 = extremely low vigor (slow initial growth with delayed emergence or reduced emergence of >60% under field conditions), 2 = poor vigor (slow initial growth and 30 to 60% reduction in emergence in the field), 3 = moderately low vigor (average initial growth with slight reduction in emergence likely under good field conditions), 4 = moderately high vigor (average initial growth with slight reduction in emergence likely in fields having suboptimal conditions), 5 = extremely high vigor (seedlings quickly emerge; exhibit rapid growth; likely to emergence under a wide array of field conditions). Offspring yield was later converted to percentages relative to the nontreated plots. Five plots from each trial, which were documented to have no parent leaf malformation at 28 DAA the previous year, were used to calculate the nontreated treatment averages for offspring grain yield. Data were subjected to correlation analysis.

Chapter 2: Summary of Conclusions

Sixteen drift trials were established over two years at the NEREC. Data from the drift trials, conducted on parent plants, were subjected to correlation analysis on seedling emergence and germination data for offspring plants to determine pairwise associations among parent and offspring observations. Auxin-like symptomology in offspring consistent with dicamba, primarily as leaf cupping, appeared in plots at the unifoliate and first trifoliate stages. Auxin-like symptoms were more prevalent in offspring collected from plants from later reproductive stages as opposed to early reproductive. The highest correlation coefficients occurred when parent plants were treated at R5 growth stage. Parent mature pod malformation was correlated with offspring emergence ($r = -0.37$, $p = 0.0082$), vigor ($r = -0.57$, $p = < 0.0001$), injury ($r = 0.93$, $p = < 0.0001$), and percent of plants malformed ($r = 0.92$, $p = < 0.0001$).

Experiments were also conducted at the R6 stage for the parent, however parent plant injury and canopy heights could not be recorded as leaf drop had started to occur approximately 2 weeks after application. Relative yield of offspring was reduced by as much as 42% at R6 and was the only parent variable to be correlated with offspring variables.

Chapter 3: Effect of Addition of Glyphosate

Materials and Methods

Field Experiment. Fields were planted with indeterminate growth habit glufosinate-resistant (glyphosate and dicamba sensitive) soybean on April 30, 2015, and May 4, 2016, at the AAREC in Fayetteville, Arkansas, and on May 14, 2016, at the Pine Tree Research Station (PTRS) near Colt, Arkansas. The soil series at PTRS was a Calhoun silt loam (fine-silty, mixed, active, thermic Typic Glossaqualfs) with a pH of 7.8 and 2.23% organic matter. Fields at AAREC were classified as Leaf silt loam (fine, mixed, active, thermic Typic Albaquults) with a pH of 6.1 and 1.75% organic matter. Trials were seeded at 345,800 seeds/ha with the intention of obtaining a population of 275,000 plants/ha given 80% germination. At PTRS, soybean was furrow-irrigated and plots at AAREC were irrigated with overhead lateral irrigation. Experiments were irrigated once weekly with at 2.5 cm if less than 2.5 cm of rainfall occurred over a 7-d period. Weeds were controlled at the experimental sites with a PRE application of flumioxazin at 70 g ai/ha (0.063 lb ai/A) at planting followed by two POST applications of glufosinate at 530 g ai/ha [0.47 lb ai/A] (Liberty) plus S-metolachlor (Dual Magnum) at 1,064 g ai/ha (0.95 lb ai/A) added to the first POST application. Treatments were arranged in a randomized complete block (RCB) design with four replications. Dicamba (Clarity), glyphosate (Roundup PowerMax), or a mixture of the two herbicides was applied at 1/64X (dicamba at 8.75 g ae/ha [0.0078 lb ae/A], glyphosate at 13.44 g ae/ha [0.012 lb ai/A]) or 1/256X (dicamba at 2.19 g/ha [0.002 lb ae/A], glyphosate at 3.36 g/ha [0.003 lb ai/A]) of the recommended rate (dicamba at 560 g/ha [0.5 lb ae/A], glyphosate at 860 g/ha [0.77 lb ai/A]) for DR cotton and soybean. Nonionic surfactant was added at 1/64X or 1/256X the full rate of 0.25% v/v (Induce) to all dicamba-alone treatments, but not dicamba plus glyphosate treatments because the glyphosate product already contained an adjuvant. Treatments were mixed using serial dilution from a stock 1X rate, and applications were made on each variety at R1 (initial flower), R3 (initial pod set), and R5 (initial seed formation). All treatments were applied using a handheld boom and CO_2-pressurized backpack sprayer with an output of 143 L/ha (15.3 gal/A) at 270 kPa (39 psi) tipped with AIXR 110015 nozzles (TeeJet Technologies). Only the center two rows of each four-row plot were treated. At 2 and 4 weeks after application, visual measurements of percent leaf malformation and percent pod malformation were recorded on a scale of 0 to 100%, with 100 being most severe. Canopy height was also recorded at 4 weeks after application. At soybean maturity, height (cm) to the terminal of three representative plants was averaged, and final pod malformation ratings were taken. Plots were harvested using a small-plot combine, and soybean grain yield was adjusted to 13% moisture. Canopy height, terminal height, and yield were later converted to a percentage relative to the nontreated control. In addition, a sample of approximately 500 seed from each plot was stored at -10°C after harvest.

Greenhouse Experiment. Seed samples from the previous field experiments were evaluated in a greenhouse at the University of Arkansas Altheimer Laboratory in Fayetteville, Arkansas. Three experiments in total were completed using offspring from both years at AAREC and 2016 from PTRS. Twenty-five seed from each sample were planted at a 2-cm depth into 33- by 18- by 13-cm trays, which were filled with potting mix (Sun Gro Horticulture). Trays from each of the four replications were arranged in a RCB design in the greenhouse. The greenhouse was maintained at 32°C daytime and 22°C nighttime temperatures (± 3°C). Natural lighting was supplemented by a metal halide lighting system and set to a 16-h photoperiod. Plants were watered daily to maintain adequate moisture levels. Twenty-one DAP, emergence (%), injury (0 to 100% with 0 being no injury and 100 being plant death relative the nontreated control), and number of plants injured were recorded for each tray. Plants were considered injured if they exhibited leaf cupping, leaf strapping, stem epinasty, or stunting. Additionally, plant vigor was rated on a 1 to 5 scale for each tray where was 1 = extremely low vigor (delayed and/or reduced emergence) and 5 = extremely high vigor (seedlings quickly emerged and exhibited normal growth). Aboveground biomass was collected at 21 DAP, dried at 66°C for 7 days, and weighed. Percent reduction in biomass was calculated relative to the nontreated control.

Chapter 3: Summary of Conclusions

Field applications were made at three growth stages (R1-initial flowering, R3-beginning pod formation, and R5-beginning seed formation) at multiple locations. Two glyphosate rates (1/64 and 1/256 of the labeled rate 870 g ae/ha [0.78 lbs ae/A]) and two dicamba rates (1/64 and 1/256 of the labeled rate 560 g ae/ha [0.5 lb ae/A]) were used in the study. Adding glyphosate to dicamba increased leaf malformation over dicamba alone when applied at R1. After R3 applications, pod malformation was greater in treatments containing dicamba and glyphosate than dicamba alone. Applications at R5 showed minimal leaf and pod malformation.

Seed from field trials were planted in the greenhouse to evaluate the offspring. The number of offspring plants showing dicamba-like symptomology was not increased with the addition of glyphosate to dicamba. Overall, injury to offspring was similar in dicamba alone and dicamba plus glyphosate treatments; however, the number of plants injured increased when parent plants were exposed to sublethal doses of dicamba at R3 and R5 compared to R1 exposure. Vigor was reduced in dicamba-containing treatments, but not glyphosate-alone treatments. Glyphosate addition to dicamba had no effect on vigor of soybean offspring.

<u>Chapter 4: Off-target Movement, Primary + Secondary Drift versus Secondary Drift Alone</u>

Materials and Methods

Drift Experiments. Field experiments were conducted in 2015 and 2016 at the NEREC. Glufosinate-resistant soybean (Bayer Credenz 4950LL) was planted in two adjacent 8-ha (19.8 A) fields on June 15, 2015, and June 13, 2016. Rows were bedded on 97-cm centers. Weed control was provided with preemergence (PRE) applications of flumioxazin at 71 g ai/ha (0.063 lb ai/A) plus paraquat at 701 g ai/ha (0.63 lb ai/A) and two POST applications of glufosinate at 595 g ai/ha (0.53 lb ai/A) plus clethodim at 76 g ai/ha (0.068 lb ai/A). Furrow irrigation was used to supplement natural rainfall. A 38- by 38-m area (0.144 ha, 0.36 A) in the center of each field simultaneously received either DGA or BAPMA dicamba applied at 560 g ae/ha (0.5 lb ae/A) with one of two Bowman Mudmaster high-clearance sprayers. Applications were made at soybean V6/V7 in 2015 and V4/V5 growth stage in 2016. Each sprayer was equipped with a broadcast boom having a 7.6-m swath tipped with TTI11003 nozzles (TeeJet Technologies) calibrated to deliver 94 L/ha (10 gal/A) at 275 kPa (40 psi) while traveling at 15 km/h (10 mph). **Reviewer's note: TTI11003 nozzles are permitted for over-the-top applications of Xtendimax and Engenia**. Five passes were made, with each sprayer (one for each formulation) simultaneously applying the herbicide to reduce variation in wind, humidity, and temperature. Wind speeds were recorded at 1-s intervals during the application. Relative humidity and temperature were recorded at the beginning and end of the application. Daily weather data (wind speed, wind direction, temperature, humidity) on a 15-s interval were recorded from 1 week before application to 3 weeks after application using a weather station placed between the two fields. Prior to application, transects were laid out in each of the eight cardinal directions extending to the edge of the field. Plots were established every 3 m from 3 to 12 m from the sprayed area, every 6 m from 12 to 36 m, every 9 m from 36 to 72 m, and every 12 m beyond 72 m until the edge of the field was reached. Two subplots consisting of four to five soybean plants per subplot were marked at each distance. The subplots consisted of soybean plants that were exposed to a) primary plus secondary drift or b) secondary drift only (any exposure more than 30 min after application). Immediately before application, 19-L buckets were placed over the soybean plants in subplots that were exposed only to secondary drift. Buckets were removed from these plants 30 minutes after completing the spray application (secondary drift only). The primary plus secondary drift subplot was never covered.

Additionally, metal rebar stands were erected with a 20 by 20 cm plywood platform affixed to the rebar at the height of the soybean canopy just before spraying. These stands were placed within the treated area and at each plot in 2015. In 2016, stands were again placed in the treated area but only in plots up to 30 m from the application. Four petri dishes (63 cm2 in size) were placed on separate stands within the treated area to catch a full rate of dicamba. Mylar cards were placed on the stands outside of the treated area to catch primary drift. In 2015, 100 cm^2 mylar cards were placed on stands at 3, 6, 9, and 12 m from the application. Mylar cards 400 cm^2 in size were used at plots starting at 18 m to the field border. In 2016, 400 cm^2 mylar cards were used from 3 to 30 m. In order to quantify primary drift, rhodamine dye (Sigma-Aldrich Company) was placed in each spray tank at 1 g/L. Petri dishes and mylar cards were removed from the field 30 min after application and placed in plastic bags indicating their location and then in a dark cooler to prevent photodegradation of the dye. Petri dishes and mylar cards were taken to the University of Nebraska Pesticide Application Laboratory in North Platte, NE, to quantify the amount of dye present on each surface using fluorimetry.

Injury to soybean within each subplot (primary plus secondary, secondary) was rated at 7, 14, and 21 days after application (DAA). Injury was rated on a 0 to 100% scale with 100% being plant death. There was no attempt to solely quantify primary drift because this would have required plants be covered for several days with buckets. Injury to soybean outside of the treated area was primarily in the form of leaf cupping, but also included leaf crinkling, epinasty, and terminal death. Two soybean plants exposed to primary plus secondary drift were harvested at 7 DAA in 2015 and four plants in 2016 directly adjacent to all distances that were rated for injury. Samples were transported on dry ice to the Arkansas State Plant Board in Little Rock, AR, and analyzed for dicamba remaining in the tissue. The method of dicamba extraction and quantification was GC/MS. The limit of detection was 1 ppb.

Dose Response Experiment. Credenz 4950 was also planted on the same day as the large field experiment in a smaller field located approximately 1 km away for use as a DGA and BAPMA dicamba rate response experiment. Applications were made on the same day as the large field experiment. Row spacing, irrigation, and weed control measures were also the same as in the large field experiment. Ten dicamba doses (56, 17.5, 5.6, 1.75, 0.56, 0.175, 0.056, 0.0175, 0.0056, and 0.00175 g ae/ha) for each formulation were applied to the center two rows of each four-row plot using a CO_2-pressurized backpack sprayer with a 1.5-m spray boom equipped with four AIXR110015 nozzles (TeeJet Technologies) with an output of 143 L/ha (15.3 gal/A) at 275 kPa (40 psi). Treatments were arranged in a randomized complete block design and included four replications. Injury ratings were taken 7, 14, and 21 DAA. Data were subjected to a two-way ANOVA to test for effects of rate, formulation, and the interaction between rate and formulation as related to injury at 21 DAA. Injury data were also subjected to regression analysis to determine goodness of fit. For each year, a model describing the natural logarithm of the dose (g ae/ha) as a function of injury (%) at 21 DAA was produced. Models could then be applied to their respective years within the large drift experiment where observed injury could be paired with an estimated rate of dicamba in g ae/ha at that particular location within the field. Whole plant tissue samples were collected 7 DAA (DGA salt only) and analyzed for the presence of dicamba. Plant heights were also collected 21 DAA and subjected non-linear regression analysis. Various exponential models were tested and goodness of fit was decided.

Chapter 4: Summary of Conclusions

The ambient air temperature was 38°C (100°F) in 2015 and 30°C (86°F) in 2016 at the time of application whereas relative humidity was 44% in 2015 and 77% in 2016. Environmental conditions are considered typical for over-the-top applications, but not necessarily worst-case conditions, especially for 2016 when the temperature was cooler than 2015. Wind speed ranged from 4 to 12 km/h (2.5 to 7.5 mph) in 2015 and 10 to 16 km/h (6.2 to 10 mph) in 2016. Winds were primarily in a north/northeastern direction during and for 48 h after application both years; therefore, soybean injury was mainly confined to the north, northeast, and east transects. Injury resulting from primary plus secondary drift generally occurred along transects at further distances following application of the DGA than the BAPMA salt of dicamba in 2015. In the 2015 experiment, the maximum distance to 5% injury from primary and secondary drift was 30 m for DGA and 24 m for BAPMA. The maximum distance to 5% injury from secondary drift alone was 12 m for DGA and BAPMA. In 2016, the maximum distance to 5% soybean injury from primary and secondary drift was 168 m for the DGA salt and 96 m for the BAPMA salt (**Table 2**). The maximum distance to 5% soybean injury from secondary drift alone of the DGA salt (120 m) was over twice as far as the BAPMA salt (54 m). However, it is unclear what impact primary and secondary drift had on crop yield or pod malformation, as these effects were not evaluated. The droplet spectrum difference in VMD was 13 microns between DGA (757 µm) and BAPMA dicamba (744 µm). In addition, the percentage of fines (droplets < 210 µm) was equivalent for the two formulations (1.57% of total spray volume).

An attempt to measure primary drift using mylar cards resulted in only two positive readings in 2015 and nine positive readings in 2016. Use of mylar cards in combination with fluorimetry does not appear accurate enough to quantify the extremely low rates of primary dicamba drift capable of causing injury to soybean.

Results from the rate response experiment indicate that soybean is equally sensitive to DGA and BAPMA dicamba. It should also be noted that six to eight hours after application of the large drift trial in 2015, a rain event occurred, likely limiting volatility by incorporating some of the herbicide into the soil.

Table 2. Soybean injury along north transect in 2016[abf]

Distance (m)	DGA					BAPMA			
	Injury[c]		Estimated Dose[d]	Foliar Residue[e]	Mylar Residue[f]	Injury[c]		Estimated Dose[d]	Mylar Residue[f]
	Primary + Secondary	Secondary Only				Primary + Secondary	Secondary Only		
3	55	40	17.292	131	1,658	55	50	17.292	2,739
6	60	45	24.818	44	0	60	50	24.818	0
9	45	40	6.995	0	0	65	40	33.521	0
12	50	40	11.338	17	0	48	40	9.415	0
18	45	35	6.995	0	0	40	32	4.062	0
24	35	30	2.22	0	0	40	40	4.062	0
30	25	15	0.552	0	0	28	15	0.86	0
36	20	15	0.252	0	2,930	20	10	0.252	0
45	20	15	0.252	0	-	15	8	0.108	-
54	15	10	0.108	0	-	10	5	0.043	-
63	10	5	0.043	0	-	5	3	0.017	-
72	8	7	0.03	0	-	5	2	0.017	-
84	7	5	0.024	0	-	5	2	0.017	-
96	7	5	0.024	0	-	5	1	0.017	-
108	8	4	0.03	0	-	3	1	0.011	-
120	5	5	0.017	0	-	1	0	0.005	-
132	5	3	0.017	0	-	0	0	0	-
144	7	3	0.024	0	-	0	0	0	-
156	7	3	0.024	0	-	0	0	0	-
168	5	3	0.017	0	-	0	0	0	-
180	2	1	0.008	0	-	0	0	0	-

[a] Abbreviations: DGA, diglycolamine form of dicamba; BAPMA, N,N-Bis-(aminopropyl) methylamine form of dicamba
[b] Wind direction during application ranged between NNE and NNW with an average of 8 and max of 12 km/h
[c] Plant injury rated on a 0 to 100% scale with 100% being plant death
[d] Dose estimated using equations generated from rate titration trial injury levels
[e] The limit for detecting dicamba was 1 ppb
[f] The estimated amount of dicamba collected from mylar cards placed within plots for measuring physical drift from 0 to 30 minutes after application
[g] Distances where no injury was observed are not shown
f. information copied from Table 7 on page 165.

<u>Deficiencies/Issues</u>:

General

1. None of the experiments involved the application of Xtendimax, the only DGA formulation registered for over-the-top applications. Therefore, the reported DGA results for the various drift studies should be considered conservative estimates.
2. None of the field trials involved over-the-top applications of dicamba to DR soybean. As a result, it is unclear how the changing foliar surface area due to dicamba damage to the soybean

plants affected volatilization. However, this is not expected to significantly impact the results of the study.

3. The method description does not detail the approach taken to ensure consistency in the identification of various injury effect levels.
4. Based on the raw data spreadsheet that was submitted to the Agency, there do not appear to be multiple replicates analyzed per trial for any of the studies conducted. As a result, while regressions are possible, the statistics generated are more reflective of model uncertainty and not measurement variability.
5. Transect density, drift observation plots, and drift observation plot positions along the transects could potentially bias the interpretation of distances to 5% effect. This could not be evaluated based on the data that was provided.

Primary and secondary drift study (Chapter 1)

6. The set of trials to evaluate primary drift were conducted using Clarity, which is not approved for over-the-top applications to soybean or cotton, and were applied using Teejet AIXR 11003 nozzles, which are not approved for use with the Xtendimax and Engenia products, dicamba products which are approved for over-the-top applications. Additionally, the droplet size was reported as very coarse, whereas on the Xtendimax and Engenia labels the mandated droplet size is ultracoarse. Therefore, the primary spray drift results from this study should be conservative estimates of what could happen in the environment.
7. The trials were conducted on small plots, *i.e.*, 8m x 30 m (0.06 A) and 8m x 60 m (0.12 A). As such, it is difficult to predict how these finding would compare to much larger fields that are typically used to grow soybeans and cotton. It is anticipated that this would have a larger impact on the secondary drift exposure rather than that generated through primary drift.
8. The date and time of the applications were not provided. While maximum and average wind speeds for each trial were provided in the report, other associated meteorological conditions (*i.e.*, temperature, relative humidity, etc.) were not provided, although the report indicates they were collected.
9. No direct measurement of the application rate was provided to confirm that the rate cited in the study was accurate.
10. No indication as to how much water was used in the tank mix.

Primary and secondary versus secondary drift only study (Chapter 4)

11. As a rain event occurring 6-8 hours after the application likely impacted the results from the 2015 trial, conclusions for primary and secondary drift are based on a single field trial.
12. The date and time of the applications were not provided.
13. No direct measurement of the application rate was provided to confirm that the rate cited in the study was accurate.
14. No indication as to how much water was used in the tank mix.
15. The report indicates that damage was assessed at 7, 14, and 21 days, but only a single set of tables, providing the injury data, were in the report. It is assumed that these data are for the 21-day interval, as the study authors indicated

    > "a model describing the natural logarithm of the dose (g ae/ha) as a function of injury (%) at 21 DAA was produced. Models could then be applied to their respective years within the large drift experiment where observed injury could be paired with an estimated rate of dicamba in g ae/ha at that particular location within the field."

16. Raw data for tissue analysis (*i.e.*, analytical lab analysis, chromatographs, etc.) were not provided in the report.